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SCIENCE IN EDUCATION

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In my brief remarks, I shall deal with two aspects of the subject: (1) the place of science in education and (2) some problems of education in science.

The origins of both pure and applied science are shrouded in antiquity and legend. Some of these legends serve to illustrate a marked difference between the place of science in education then and now. According to one of these legends, the god Hermes, who knew the secrets of nature, used to come to earth in human guise to work in his laboratory. The results of his experiments were placed in vessels which were tightly closed and sealed to keep them from curious eyes. Hence arose the term "Hermetically sealed." By another legend, a group of fallen angels settled on earth and took human wives. They employed these wives to write the secret formulae of science in a great volume known as *chemna,* whence came the names chemistry and alchemy. Today, the press and radio of the world are broadcasting the discoveries of science, and your job as science teachers is to educate the youth of the country in scientific methods and facts.

The contrast is striking. In early days science was secret; its devotees were a secret cult; it was like an aristocracy,—not for the common people. Today, science is an integral part of the daily interest and life of everyone,—science has become a democracy.

Along with this democratizing of science has come an increasing freedom from superstition. The Greeks had made good progress in the transition from superstition to science, when the invasions of Europe by the mid-Asiatics in the early centuries of the Christian era, together with the contacts with the Orient established over trade routes, brought back a long era of superstition which has delayed the attainment of a realistic and rational conception of the world. These superstitions led to belief in the philosophers' stone, witches, and tokens. Even now superstition is not unknown, even among scientists. Two days ago, a well-known scientist, to prove his complete freedom from superstition, said that he always

asked for room 13, or a room on the 13th floor. Apparently, this made him feel better. But there is no doubt that superstitions fade as the light of science grows brighter.

Now this democratization of science and this banishing of superstitions are of enormous significance. I do not dwell on the value of science in increasing productive power, decreasing hours of labor, adding innumerable conveniences to living, banishing disease and bodily discomfort, permitting quick and wide communication of ideas, and the like. These things we all recognize as out-growths of science, and they speak for themselves. But I have in mind a far more important value of science.

Superstition is a matter of the emotions; science is a matter of reason. The conquering of superstition by science is a triumph of reason, or intelligence, over emotion or fear. Such a triumph is, I believe, an absolute essential if a democratic form of government is to be successful. A man whose mind is trained to view situations objectively, to draw rational conclusions from observed facts, to plan his course intelligently in the light of these facts and conclusions, is a man who is a safe citizen in a self-regulating society, *i.e.,* in a democracy. On the other hand, a man who is not trained or capable of thinking rationally, who is governed by his emotions and prejudices, is an unsafe member of a democratic society,—an element of instability.

Let me give a few examples to suggest what I mean. The teachers' oath laws have been sponsored by a group of emotional citizens who believe sincerely in one hundred per cent Americanism. They, therefore, proceed impulsively to allow themselves to get worked up to an emotional pitch over an imaginary situation and to propose a cure which is childishly futile for accomplishing the desired objective. To my mind the teachers' oath bill, in itself, is not harmful except as a nuisance. The serious thing is the fact that so many voting citizens can be so blind to the logical weakness of their case as to take righteous satisfaction in feeling that they have performed a national service. It is the same kind of emotional and mob-psychology which burned witches, drove the pilgrims out of Europe, and has led many nations into useless wars.

Take, again, matters of political or social reform. The rational approach starts with a study and analysis of the situation, and proceeds to search for a solution which will retain present good and eliminate present evil, with careful consideration of results. The non-scientific approach is to try this or that on erratic hunch, to try to perform a miracle as a magician pulls a rabbit out of a hat. The results are likely to be exceedingly costly.

These illustrations could be multiplied, but they will serve to suggest an important aspect of the teaching of science,—the development of the habit and power of thinking logically, of checking theories against facts, and of acting under guidance of reason. Thomas Jefferson, himself a scientist, saw the values of scientific education to a democracy and he "coupled freedom and science as conditions of progress." (Bowman, *Science,* Dec. 6, 1935.) He believed in thinking for himself, saying: "I never submitted the whole system of my opinions to the creed of any party of men whatever, in religion, in philosophy, in politics, or in anything else, where I am capable of thinking for myself. Such an addiction is the last degradation of a free moral agent. If I could not go to heaven except with a party, I would not go there at all."

In these days of complex problems and of increasing tendency to emotional group or mob action, it is more than ever before necessary that our youth be trained to think and act rationally. Science is the best possible training for developing this capacity. Therefore, I believe that it is highly significant that science is now not a secret cult but a matter of universal interest and concern. I, therefore, add this argument to the more common arguments, based on

cultural and practical value, as justification for increased emphasis on science in the programs of our schools and colleges.

The second section of my remarks has to do with a problem of the method of education in science. A rather basic question is: "Which is more important for the teacher, to have thorough knowledge of the subject to be taught, or to have expert training or native skill in the abstract art of teaching?" I shall not answer this question categorically, for obviously both are necessary. I would rather speak of the mode of approach in the teaching of science.

Undoubtedly, the easiest and laziest method of conducting a class in science is to assign a lesson from a text book, quiz the pupils on their mastery of this lesson, and then assign the next lesson. In more advanced university work, an equally easy method is to lecture. Lecturing satisfies the self-esteem of the lecturer, who takes artistic pleasure in the logic and skill with which he covers his subject, and who avoids nearly all contacts with his students which might disturb the perfection of the presentation. Undoubtedly, also, these are the world's worst methods of teaching science. A real science teacher is far more than a taskmaster or a stoker, and science does not consist of learning lessons by heart or taking notes. In fact, an argument can be made that the habit of learning, by memory, with which so much of our education is concerned, is a handicap rather than an asset to real mastery of the method and spirit of science.

Science is not a technique or a body of knowledge, though it uses both. It is rather an attitude of inquiry, of observation and reasoning, with respect to the world. It can be developed, not by memorizing facts or juggling formulas to get an answer, but only by actual practise of scientific observation and reasoning. The teacher, to be effective, must have the same attitude as the pupil, after the method of Socrates.

There is no stimulus like the joy of discovery, and it is often a wonder to me that any interest of students in science ever survives the year upon year of learning to which they are often subjected without ever tasting the joy of an original discovery or idea, however elementary. There is all the difference in the world between running a laboratory to verify the laws that have been learned in the text book and running it to bring out or suggest these laws in advance of the text book. The latter method is slower, and far more difficult for teacher and pupil alike; but the former method is not really science at all,—merely illustration and technique.

I have occasionally known teachers who really did scientific work with their pupils, and never once have I known it to fail of results. It is often said that elementary teaching in science is a highly developed art, whereas teaching on the higher levels, in the graduate schools, is very poorly done. It is also generally believed that teaching becomes more difficult in the higher levels. I think, in a way, both these statements are wrong. The best and also the easiest teaching is done by the professor who is working with his graduate student on a research problem. Here all thought of pedagogy is thrown to the winds; the teacher and student are collaborators on a job that taxes the resources of both. The student learns by example and by his own mental effort.

Now, I perfectly well realize that I have presented an exaggerated case, and that there is a great deal to be said for training of teachers in educational methods. But I firmly believe that no element in the training and environment of science teachers is so valuable as that which keeps them in continual live touch with the progress of science itself so that, through their own interests and example, their students may see science as a live subject and feel that they share some part, however significant, in its progress. This is a continual challenge to the best ingenuity of science teachers and a guide as to those activities and contacts which will be of greatest value to them in their teaching work.